TECHNICAL NOTE: PEBBLE BED MODULAR REACTOR (PBMR) REVIVAL PLAN.

Executive Summary

This short report briefly describes the reasons why the South African government can no longer afford to keep its Pebble Bed Modular Reactor (PBMR) Project under care and maintenance mode. The emergence of the decentralized and distributed small scale power generation technologies have created a need for nuclear power companies to relook at the Small Modular (Nuclear) Reactors –abbreviated SMRs in order to compete in decentralized and distributed power generation applications set by the wind and solar power industry. Powerful countries have committed funds to invest in SMRs Projects. South Africa was a world leader with its SMR Project called PBMR up until it was put under care and maintenance mode in year 2010.

This report highlights a snapshot of the main SMRs Projects globally that will capture the market that South Africa should be pursuing with its PBMR Project. There are over 8 countries that have committed investments including China, USA and Britain already committed reasonable funds to accelerate the development of the SMRs Projects.

Fortunate enough a few of the world's leading countries like USA, Canada, China and Russia still hold the South African PBMR Project in high regard due to the great deal of work that was achieved before 2010 when it was put under care and maintenance mode. These countries are also aware of the systems, the IP and Patents that South African PBMR Project already developed and own that it would make more sense for them to partner with South Africa than developing them from scratch. Two of these are the Helium Test Facility for High Temperature Gas Reactor and the TRISO Fuel Manufacturing Plant that is ready to manufacture the fuel on a commercial scale for the world market.

. An amount of about R 50 Million is immediately required to be budgeted for doing the front end loading work that will inform the position of the RSA PBMR Project in relation to the other SMRs Projects around the world. It is estimated that it would cost about R 1.5 Billion to take the RSA PBMR Project to 'Financial Close' whereby private investors will invest in numbers. China is mostly likely to share the investments costs of the R 1.5 Billion Project Development Costs with South Africa.

Below is a very brief report that gives the perspective of the renewed interest in the development of the SMRs globally due to the emergence of the decentralized and distributed electricity generation technologies plus the added advantages that come with SMRs such process heat for industries, sea water desalination and agricultural watering industry offsets solutions.

1. Brief Review on Why South Africa's PBMR Project Should be Revived:

This framework plan describes the compelling reasons for reviving the South African Pebble Bed Modular Reactor (PBMR) Project. The PBMR Project falls under what is called Small Modular (Nuclear) Reactors, simply abbreviated as SMRs. SMRs are classified as any nuclear power reactors that can only produce power below 300 MWe per reactor unit and are relatively easy to deploy in terms of capital costs,

construction costs and construction timelines. Any nuclear reactor that produces 400 MWe or more power per reactor is classified as a family large scale Nuclear Power Plants (NPPs). The size of one PBMR Unit is between 80 MWe and 300 MWe, thus it falls under the family of SMRs. The PBMR Project is 100% owned by the South African Government. This project was put under 'Care and Maintenance' Mode in year 2010/2011 after the South African government had already expended over R 9 Billion on it. At the time of freezing the PBMR Project a 150 MWe unit was under design, engineering and contracting. The South African government had requested two requirements from the Executive Management Team of the PBMR Project:

1. Find private or international investors to co-invest with the RSA Government for the project implementation costs.
2. Secure Orders from 'prospective' customers and markets for a minimum number of units to achieve break even point.

The main products the South African PBMR Project are small scale Electricity Generation of up to 300 MWe per unit plus what is called 'Process Heat' for any industrial applications that need heating for manufacturing. When the RSA Government asked the executive management to ensure the PBMR project meets the two conditions above, the electricity market was dominated by large scale power plants. However, 10 years later on the situation has changed quite dramatically whereby small decentralized electricity generation power plants have disrupted the market for large scale power plants, particularly owing to the arrival of small scale Wind and Solar Power Plants. The big wave of these decentralized small scale power plants fits and suites the business case of the SMRs or the PBMR Project electricity generation potential. This then puts the PBMR Project in a very good position to easily meet both the RSA Government requirements above. In fact most leading countries have embarked on accelerating their SMRs programmmes. South Africa is still regarded third as a leader in SMRs following China and Russia which are moving their SMRs power plants to commercial operation in the next 12 months to 24 months.

Quite a number of countries recently committed investments into new SMRs Programmes for their own domestic robust decentralized electricity generation and process heat applications as well for selling their SMRs units to the international markets.

The leading countries that have embarked on SMRs Programmes are briefly described in section 2 below.

2. The Global Background on Small Modular Reactors (SMR's)

The following countries are leading program for the commercialization of the SMRs:

Western and European Countries:

2.1 . United State of America:

i) **Terrapower -** www.terrapower.com.

- Bill Gates is the owner of Terrapower. His Company is working with the Department of Energy to develop SMRs.
- Both Mr. Bill Gates and the USA Energy Department have committed funds to develop SMRs with planned implementation dates around year 2027/29.

ii) **NuScale** -https://www.nuscalepower.com/

- NuScale is privately owned. It is developing SMRs with average size of 60 MWe that will be deployed for electricity generation, process heat applications, sea water desalination and enhancement of agricultural irrigation water.

iii) **Envisaged Markets** - The Americans are developing their SMRs machines for their own huge ***Energy and Industrial Process Heat*** demand market, the Canadian market and the African market.

iv) **Holtec International** - https://holtecinternational.com/company/divisions/smr-llc/

- Holtec is developing SMRs in collaboration with Ukraine with average size of 160 MWe. Ukraine will set up Fabrication Plant for the SMRs Reactors that Holtec intends to market worldwide.

2.2 . Canada:

v) **StarCore** - http://starcorenuclear.ca/

- StarCore is developing SMRs with average size of 30 MWe – 150 MWe that will be deployed for electricity generation and process heat applications in Canada, Africa and USA.
- It is currently proposing 23 SMRs machines to the Nigerian Government for deployment between year 2027 and 2040.

2.3 . United Kingdom (UK)

vi) **Rolls-Royce**- https://www.rolls-royce.com/

- Rolls-Royce is developing SMRs with average size of 60 MWe that will be deployed for electricity generation, process heat applications and sea water desalination.
- The new British Prime Minister recently approved 18 Million pounds (about R 334 Million) to assist the Rolls-Royce Group to accelerate the development of its SMRs.

2.4 China

vii) **HTR-PM** –by Chinese University.

- China currently has a 10 MWe SMR in full operation.
- It is currently constructing a 200 MWe SMR Project that is earmarked for commercial operation in the first quarter of 2020.
- **Envisaged Markets** - The Chinese are developing their SMRs machines for their own huge ***Energy and Industrial Process Heat Applications*** demand market and the African market.
- China holds the South African PBMR Project in high regard and is prepared to partner with South Africa on PBMR to develop it for the African Market as well as the world markets.

2.5 Republic of Rwanda

- The Rwandan Government has stated that it is committed to procure up to 200 MWe of New Nuclear Power from the SMRs technology suppliers.
- Media Reports state that the Russian Government owned Civil Nuclear State Atomic Company Rosatom is a front runner for this 200 MWe Rwandan proposal.
- If Rwanda opens it up for public bidding the Chinese, Americans and the Canadians are mostly likely to put in bids.
- It is on this basis that South Africa simply cannot longer afford to postpone the resuscitation of its own SMR Program called Pebble Bed Modular Reactor (PBMR) Project.

2.6 Democratic Republic of Congo:

- The Congolese Government through its Minister of Energy has signed a Letter of Intent (LOI) with KANDA INVESTMENT (PTY) Ltd to bring a total 1000MWe to the grid to alleviate the deficit of Electricity mainly in the mining industry.
- Kanda Investment is the leader in the SMRs in the DRC, and the only company allocated an LOI with intent to turn it into a PPA after the feasibility studies have been completed. Kanda Investments will be the strategic partner to access the DRC Market.

3. Funding Models/Options for Reviving the PBMR Project

The following funding stages of the PBMR are estimated:

- Lobbying and interim overheads (R10M)
- Front-end loading (full business plan R30M)
- Development to financial close (R1.5 billion). This will be co-funded with China.

- Capital Investment for one 165 MWe unit up to R15billion. The commercial units will be funded on firm orders by customers.
- The Chinese HTR-PM 200MWe estimated R8 billion with some exlusions.